TSP3222
DUAL 30V - 2A
PROGRAMMABLE
POWER SUPPLY

Racal Mobilcal Ltd.
Test Equipment Maintenance Department
Location:- H2
ID 1159

THURLBY
THANDAR

TSP3222
DUAL 30V - 2A PROGRAMMABLE POWER SUPPLY

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Software

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Manual

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Introduction

The TSP3222 programmable power supply is a high performance dual-output quad-mode linear power supply with remote sensing and featuring full remote operation via a GPIB interface; the GPIB protocol and command syntax meet the ANSI/IEEE Standard 488.2 1987. The instrument is housed in a half-rack width, 3U high steel case; a 19-inch rack mounting kit is available as an option.

The power supply takes input from the keypad or from the GPIB and uses this data to set up and control the output modules. The 24 character x 2 line alphanumeric liquid crystal display normally shows the voltage and current for each module and is additionally used to prompt the set up of the instrument's more advanced features.

Capabilities of the instrument include:
Operation in constant current or constant voltage modes with automatic cross-over. The outputs are protected against forward and reverse voltages. Load and line regulation are better than 0.01% with ripple and noise typically better than 1mV. Linear operation ensures that RFI is minimised.

Two identical, independent 0-32 Volt, 0.001-2 Amp modules in the same case and sharing the same GPIB bus address.

Output voltage adjustable in 10mV steps. Current limit adjustable in 1mA steps. Output current and output voltage read back to 12-bit accuracy.

User-definable over-voltage protection available independently for each output module.

Built in thermal protection.

300 Volt isolation between outputs and either output and ground.

Outputs may be internally connected in series when higher output voltages are required or in parallel when larger output currents are required.

Outputs may be specified to voltage track; thus an adjustment to one such output will be immediately mimicked on the other tracking output. Each output may be specified to have a unique current limit.

Non-volatile storage at power down. When power is applied to the instrument the settings will be restored to those immediately prior to the interruption of power.

Setting memories. 25 setting memories are available for the complete instrument set-up. These may be recalled at any time and are retained whilst the power is off.

A National Instruments LabWindows* device driver is available as an option; Labwindows* is an interactive software package which permits fast, simple GPIB programme generation and debugging on DOS-based computers.

* Labwindows is a trademark of National Instruments Corporation.

1. Technical Specification (each output)

Output Voltage:

Range:	0 to 32V; 2V to 64V in series mode
Resolution:	10mV
Accuracy:	0.05% +/-10mV
Temperature coefficient:	<50ppm/^{o}C; typically 20ppm/^{o}C
Line regulation:	0.001% for 10% line change
Load regulation:	0.005% for 50% load change
Ripple and noise:	Typically <1mV rms
Transient response:	<100us to within 50mV of setting for 50% load change

Output Current:

Range:	1mA to 2A; 1mA to 4A in parallel mode
Resolution:	1mA
Accuracy:	0.1% +/-1mA
Temperature coefficient:	<75ppm/^{o}C; typically 40ppm/^{o}C
Ripple and noise:	Typically <0.2mA

Voltmeter:

Resolution:	10mV
Accuracy:	+/-(0.05% of reading + 10mV)

Current Meter:

Resolution:	1mA
Accuracy:	+/-(0.1% of reading + 1mA)

Over-Voltage Protection:

Range:	1V to 35V; 3.2V to 70V in series mode
Resolution:	0.2V
Accuracy:	+/-(2% + 0.2V)

Thermal Protection: On both outputs

Output Protection:

Forward voltage:	Up to OVP setting.
Reverse voltage:	Diode clamped for reverse voltages and up to 3A reverse current.

Output Mode: The power supply operates in constant current or constant voltage modes with automatic cross-over. A display annunciator (flashing delta sign) indicates constant current mode.

Output Switch: Isolates the output and permits voltage and current limits to be set up before connecting the load.

Output Terminals:

Front panel:	4mm terminals on 19mm (.75") spacing.
Rear panel :	Screw terminals for sense and output.

Output Impedance:

Constant Voltage:	Typically <10mOhm at 1kHz
Constant Current:	Typically 50kOhm with voltage limit at maximum

Response Time over GPIB for 10V step: <5ms

Power Requirements:	
Input Voltage:	Internally set for 110, 120, 220 or 240VAC 50/60Hz
Input Voltage Range:	+/- 10% of voltage setting
Power Consumption:	300VA
Environmental Operating Range:	5°C to 40°C, 20% to 80% RH
Environmental Storage Range:	-20°C to +60°C
Size:	210mm x 129mm x 380mm (W x H x D)
Rack Mounting	Half rack width x 3U high. An optional rack mounting kit is available.
Weight:	11kg

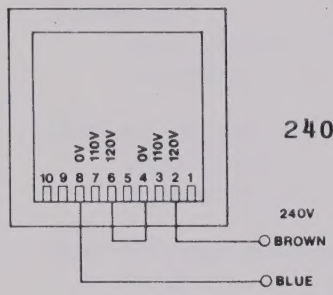
2. Installation

2.1. MAINS OPERATING VOLTAGE

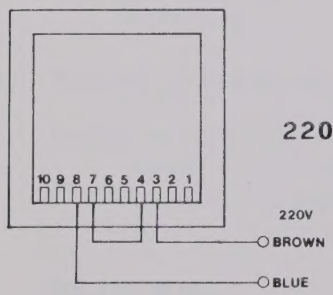
Check that the operating voltage of the instrument shown on the rear panel is suitable for the local supply. Should it be necessary to change the operating voltage range proceed as follows:

1. Ensure that the instrument is disconnected from the AC supply.
2. Remove the 4 side screws holding the case upper and lift off upper.
3. Remove the five screws retaining each of the analogue boards and part the boards to reveal the 3 mains transformers.
4. Change the transformer connections following the diagrams below.
5. Reassemble in the reverse order.
6. Change the fuse type if necessary.

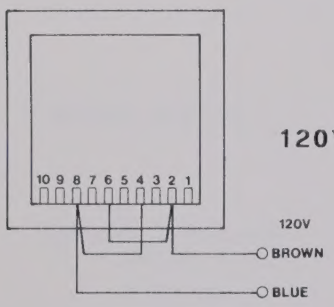
LARGE TRANSFORMERS



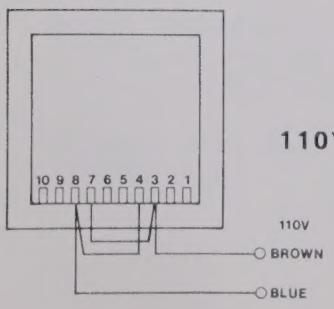
240V Operation



220V Operation

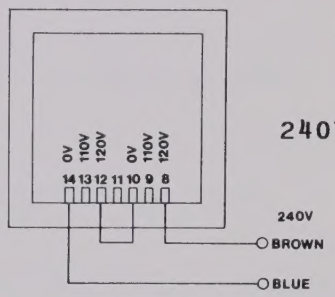


120V Operation

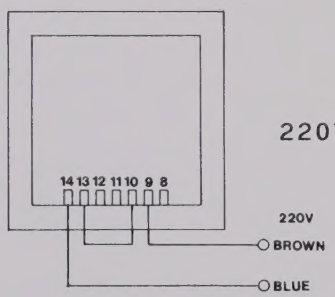


110V Operation

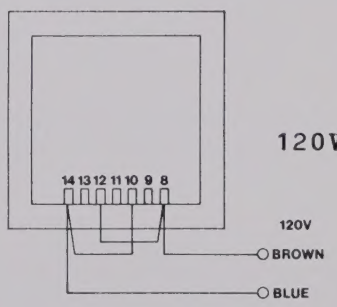
SMALL TRANSFORMER



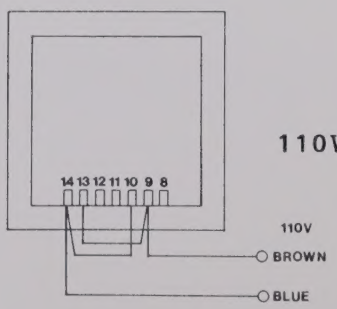
240V Operation



220V Operation



120V Operation



110V Operation

2.1.1 Fuse

The correct fuse type is:

1.6A 250V HRC time-lag, 20mm for 220-240V
3.15A 250V HRC time lag, 20mm for 110-120V

Make sure that only fuses with the required rated current and of the specified type are used for replacement. The use of makeshift fuses and the short-circuiting of fuse holders are prohibited.

2.1.2. Mains Lead

When a three core mains lead with bare ends is provided this should be connected as follows:

BROWN	-	MAINS LIVE
BLUE	-	MAINS NEUTRAL
GREEN/YELLOW	-	EARTH

When fitting a fused plug a 3 amp fuse should be fitted inside the plug. As the colours of the wires in the mains lead of this apparatus may not correspond with the coloured markings identifying the terminals in your plug proceed as follows:

The wire which is coloured green-and-yellow must be connected to the terminal in the plug which is marked by the letter E or by the safety earth symbol ⏚ or coloured green or green-and-yellow.

The wire which is coloured blue must be connected to the terminal which is marked with the letter N or coloured black.

The wire which is coloured brown must be connected to the terminal which is marked with the letter L or coloured red.

WARNING! THIS APPARATUS MUST BE EARTHED

Any interruption of the protective conductor inside or outside the apparatus or dis-connection of the protective earth terminal is likely to make the apparatus dangerous. Intentional interruption is prohibited.

2.2. OTHER CONSIDERATIONS

Since the unit will generate considerable heat when supplying high currents at low voltages, ventilation must not be restricted.

2.3. RACK OPTION

An optional rack mounting kit is available which is supplied with assembly details. For further information contact Thurlby-Thandar Ltd or their agents.

3. Manual Operation

The following sections describe the manual operation of the TSP3222 power supply.

3.1. FRONT PANEL

Figure 1 shows the instrument front panel. The ON/OFF switch is used to apply line voltage to the instrument. When switched to ON the instrument will be powered and the start-up procedure will be executed; this includes initialisation plus a complete self-test of the output modules and will take approximately 10 seconds to complete. If all is well the settings from the last power-down will be installed and the instrument will be ready for use.

The output terminals are located to the right of the power switch. The red terminal is positive and the black terminal is negative. Connection to the output terminals can be made with any of the following: 2mm or 4mm plugs, spade terminals or wire ends. To minimise voltage drop, the connecting leads to the load should be of an adequate wire gauge and be kept short. The output terminals are duplicated on the rear panel, together with the sense terminals.

The keyboard is located above the output terminals. This consists of 23 keys and a red and a green led indicating the overall instrument output status. The use of the keyboard to control all instrument functions is discussed in the following sections.

Above the keyboard is the liquid crystal display consisting of 2 lines each of 24 characters. The display normally shows the voltage and current for each output module but this will change temporarily as selections are made. The area below the display contains one led for each module indicating that module's output status, and lines to divide the display into areas where the values of the respective parameters are shown. Voltage values are shown in the top line and current values in the bottom line, the letters V and A to the right of the display serve as a reminder of this. The display contrast control is located to the lower right of the display and may be adjusted by a small screwdriver or trim tool inserted into the hole in the panel.

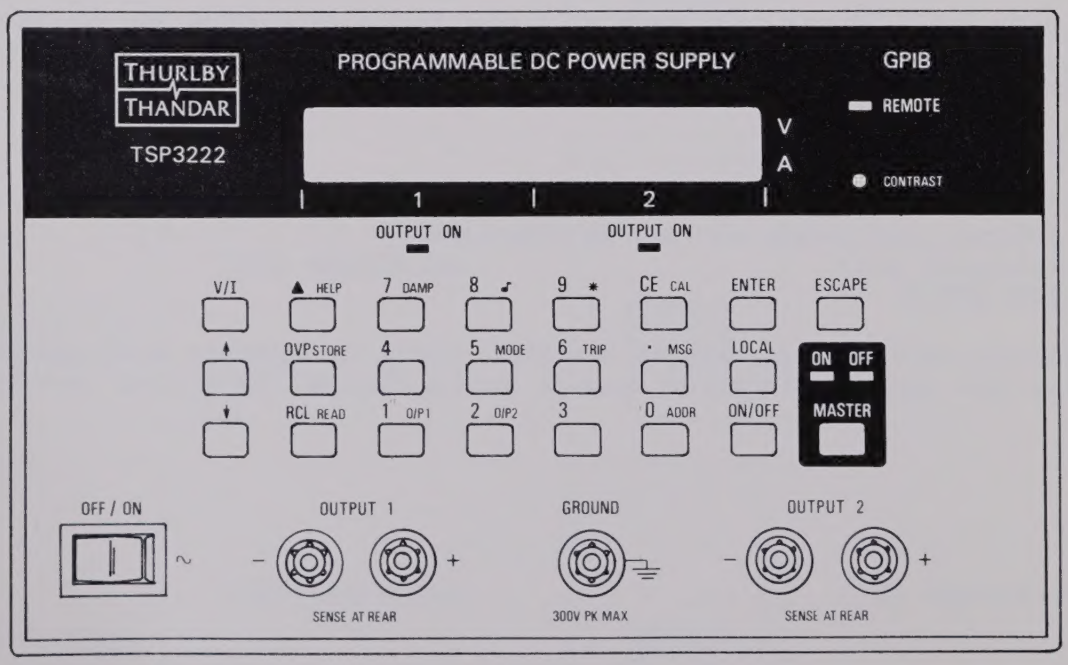
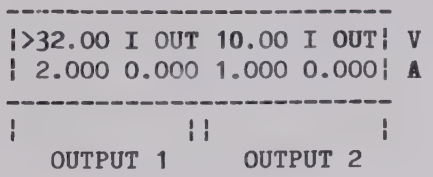


Figure 1.

The following sections contain a display example, such as shown below, for each operation.



3.2. GENERAL PRINCIPLES OF OPERATION

There are 2 'levels' of display information known as 'normal level' and 'menu level'. Normal level, as the name implies, is shown most of the time and the switch to menu level is made automatically when required. This will happen when, for example, the user requires to examine, and optionally change, the GPIB device address. In general the display level will switch whenever a request is made to examine or change a parameter which is not shown at normal level.

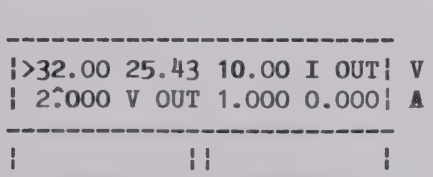
Access to parameters which are not shown at normal level is either by a normal level key e.g. **OVP** or by entering a 'function sequence'. This is a sequence of 2 keys consisting of the blue function key followed by another key which defines the particular parameter required. These secondary displays are called menus and are accessed at menu level. Pressing the blue function key twice will produce a help list of all available sequences. Keys which allow entry to a function sequence have the mnemonic printed above then in blue.

3.2.1. Normal Level

The display is divided vertically into two equal areas and each output module uses one half. The display is described for only one output as the other output is identical. Each output display area is subdivided vertically into two sections.

The left-hand section shows the voltage and current limit values. These are supplied by the user or down the GPIB.

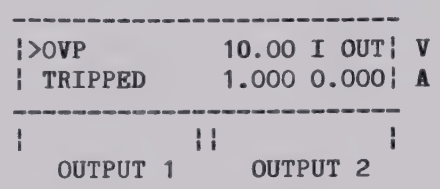
The right-hand section, headed I OUT, shows the actual current which is being supplied to the load. If the output status is set to off (indicated by the output led being **off**) or the Master output control is off (indicated by the green OFF led being **on**) this value will be zero (0.000). If the output status is set to on (indicated by the output led being **on**) and the Master output control is on (indicated by the red ON led being **on**) this value will show the output current being drawn from the supply. If the load is demanding more current than the current limit value shown in the left-hand section then the supply will enter constant current mode and the display will change as shown below



The right-hand section now shows the actual output voltage to which V OUT has fallen due to the supply entering constant current mode, a condition which is indicated by the flashing delta sign (^) above the decimal point of the current value in the left-hand section of the display. The output current is

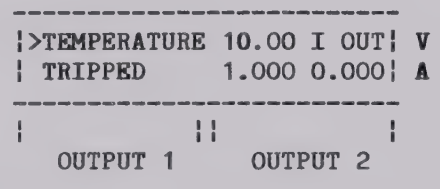
then equal to the limit value.

The Over-Voltage Protection (OVP) value for each supply is not shown; however, it is active and if at any time the actual value of the output voltage exceeds the set value the OVP circuit will immediately shut down the output, thus avoiding any damage to the circuit under test. The OVP circuit will protect against adjustments by the user or the GPIB, external voltages impressed across the output terminals, or a failure in the circuitry of the instrument itself. If the OVP circuit trips for any reason the display will change as shown below.



The output will then be shut down, i.e. the tripped output will be switched off, and the cause of the trip will be investigated. If the TRIP MODE is set to ALL then both outputs will be shut down while the investigation proceeds. If the TRIP MODE is set to SINGLE only the affected output will be shut down.

If the instrument overheats a thermal trip will occur and the display will change as shown below.



The output will then be shut down, i.e. the tripped output will be switched off. If the TRIP MODE is set to ALL then both outputs will be shut down. If the TRIP MODE is set to SINGLE only the affected output will be shut down. This condition will continue until the instrument cools to below the trip temperature value; a self-test will then be performed on the output. If all is well the output will be usable again, otherwise the output will be marked as failed.

If an OVP or temperature trip, occurs while the outputs are in Series Mode, Parallel Mode or Tracking Mode both outputs will be shut down regardless of the TRIP MODE setting. The actions described above will then be taken and if no faults are detected the mode will be reinstated automatically.

3.2.2. Menu Level

The following operations cause a switch to menu level display. Most of these operations are initiated with a function sequence. A complete list of operations is presented below for reference.

Function sequence operations

Key sequence	Mnemonic	Operation
FUNCTION FUNCTION	**HELP**	Show function sequence key definitions.
FUNCTION 0	**ADDR**	Display/change GPIB device address
FUNCTION 5	**MODE**	Display/change mode (tracking, series, parallel)
FUNCTION 6	**TRIP**	Display/change trip mode (OVP, thermal trip)
FUNCTION 7	**DAMP**	Display/change readback meter damping
FUNCTION 8		Display/change buzzer status
FUNCTION 9	*	Reserved for later enhancements
FUNCTION RCL	**READ**	Read instrument settings from specified store without altering the instrument set-up
FUNCTION .	**MSG**	Display GPIB messages on LCD
FUNCTION CE	**CAL**	Enter calibration mode
FUNCTION OVP	**STORE**	Store instrument settings to specified store

Direct operations

OVP	Display/change OVP trip voltage for selected output
RCL	Recall instrument settings from a specified store.

When at menu level the display contents will depend upon the value which is being changed.

3.3. NORMAL LEVEL OPERATIONS

The following section describes the operations which are active at normal level and which do not cause a switch to menu level.

3.3.1. Output Module Select

Before making changes to the parameters of a particular output (set voltage, set output status, etc.) it is necessary to 'select' the required module. The selected module will be indicated by a pointer in the display (>). To change the selected module press the blue **FUNCTION** key followed by the number key corresponding to the required module e.g. **FUNCTION** 2 will select output 2. The pointer will be positioned to the left of the selected output module in the display.

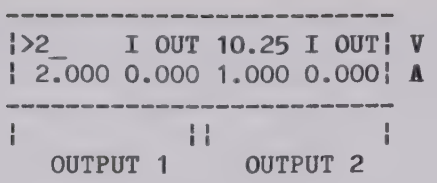
3.3.2. Setting Voltage and Current

Once a module is selected the pointer will be pointing to the set voltage or set current value for that module in the display. The pointer will move alternately between the voltage and current limit values when the **V/I** key is pressed.

The selected value may be changed by pressing the **UP-ARROW** or **DOWN-ARROW** keys which will increment or decrement the value by one step; the step sizes are 10mV and 1mA for voltage and current respectively.

It is also possible to enter a value directly from the numeric pad followed by the **ENTER** key. As the entry is made the numbers will appear in the display. Corrections may be made using the **CE** (Clear Entry) key and re-entering the number. Values entered will be in Volts or Amps and the decimal point key (.) may be used to enter the exact value required. Once a numeric key or point is

entered the selected item will change and a flashing cursor will appear as shown below.



Further numeric entries will appear at the cursor position and the cursor will move right. The **CE** key will move the cursor left one position and delete the digit at that position. Pressing the **ENTER** key will change the corresponding value to the newly entered value. The **ESCAPE** key may be used at any time to abort the entry and leave the value unchanged.

3.3.3. Output Status

The output status will alternate between ON and OFF when the **ON/OFF** key is pressed; the status will be indicated by the output led.

3.3.4. Master Output Status

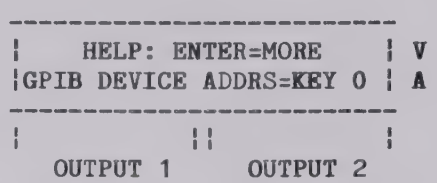
The **MASTER** key will alternately switch between all outputs OFF and those outputs ON whose output status is set to ON; thus it is possible to simultaneously apply power to multiple rails in a system under test. Master output status is shown at all times by the red ON led and the green OFF led.

3.4. MENU LEVEL

The following sections contain information on operations which cause a switch to menu level display. Most of these operations are initiated with a function sequence.

3.4.1. HELP - FUNCTION FUNCTION

This operation displays attributes of the keys which have a secondary function. It may be used to simply find out what is available but a specific function can be entered directly at any point. Pressing the blue **FUNCTION** key twice will produce the following display.



This is the first HELP menu. Subsequent HELP menus may be displayed by successive presses of the **ENTER** key.

From any of the HELP menus pressing any one of the keys with a secondary function will immediately cause that operation to be entered (even if that key is not on the display at the time). The operation will be started just as if the short function sequence had been used and will function in the usual way as described below.

Pressing the **ESCAPE** key whilst in the HELP menu will return to normal level with no changes.

3.4.2. ADDR (Display or change GPIB device address) - FUNCTION 0

Sets the device address of the instrument on the GPIB. The value is retained in non-volatile RAM and does not need to be set every time the instrument is powered up. The default value when the instrument is shipped is 11.

```
-------------------------
|GPIB DEVICE ADDRESS: 11 | V
|  NEW VALUE? _          | A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

A new value may be entered from the numeric keypad and terminated by the **ENTER** key. The **CE** key may be used for corrections. The new value will become effective when the **ENTER** key is pressed. Pressing the **ESCAPE** key will return to normal level with no changes.

3.4.3. MODE (Display or change mode - tracking, series, parallel) - FUNCTION 5

This operation gives access to the quad-mode capabilities of the instrument.

Isolated

```
-------------------------
|MODE: ISO 1 2          | V
|TKG:       MD=↑↓ TK=1-2| A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

Tracking

```
-------------------------
|MODE: ISO 1 2          | V
|TKG: 1-2   MD=↑↓ TK=1-2| A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

Series

```
-------------------------
|MODE: SER 1 2          | V
|TKG:       MD=↑↓ TK=1-2| A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

Parallel

```
-------------------------
|MODE: PAR 1 2          | V
|TKG:       MD=↑↓ TK=1-2| A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

The **UP-ARROW** and **DOWN-ARROW** keys are used to select ISOlated, SERies and PARallel modes. Pressing key **1** followed by key **2** will set tracking mode; repeating this will turn off tracking mode. NOTE that tracking mode is allowed only in conjunction with isolated mode. When the required mode has been selected pressing the **ENTER** key will install it. Pressing the **ESCAPE** key will return to normal level with no changes.

Pressing the **CE** key allows the instrument to be cleared and the default parameters to be installed. The display will change to

```
-------------------------
|SET DEFAULT PARAMETERS? | V
|PRESS CE TO CONFIRM     | A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

pressing the **CE** key again will perform the above action and return to normal level. Pressing any other key will return to the mode menu with no changes. The default parameters are set as follows: All outputs are set to minimum voltage, minimum current, maximum OVP, meter damping off and output OFF. The mode is set to 0 with no tracking. Shutdown mode is ALL and Master is OFF.

When the mode is changed the Master output status will be set to OFF.

Examples of the normal level display and output connection requirements for different modes are shown below.

ISOLATED MODE

```
-------------------------
|>32.00 I OUT 23.00 I OUT| V
| 2.000 0.000 1.000 0,000| A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

Output connections for each supply are available from the front panel red and black terminals or from the rear panel together with the sense terminals. The two supplies may be set completely independently in all respects.

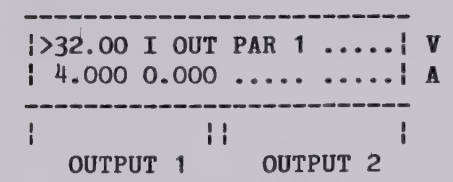
SERIES MODE

```
-------------------------
|>64.00 I OUT SER 1 .....| V
| 2.000 0.000 ..... .....| A
-------------------------
|          ||           |
   OUTPUT 1     OUTPUT 2
```

Output connections for the single 64 volt 2 amp supply are as follows.
Front panel black (-ve) terminal of output 1 is the new negative terminal.
Front panel red (+ve) terminal of output 2 is the new positive terminal.
Rear panel negative terminal of output 1 is the new negative terminal.
Rear panel -sense terminal of output 1 is the new -sense terminal.
Rear panel positive terminal of output 2 is the new positive terminal.
Rear panel +sense terminal of output 2 is the new +sense terminal.
The front panel red terminal of output 1 and the black negative terminal of output 2 are open circuit as are the corresponding rear panel terminals.

It is not possible to select output 2 and all parameter changes will be made to output 1 for which it is now possible to set to 64 Volts.

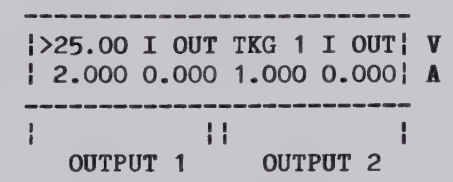
PARALLEL MODE



Output connections for the single 32 Volt 4 Amp supply are those normally used for output 1, both front and rear panels. The terminals of output 2 are open circuit.

It is not possible to select output 2 and all parameter changes will be made to output 1 for which it is now possible to set to 4 Amps.

TRACKING MODE

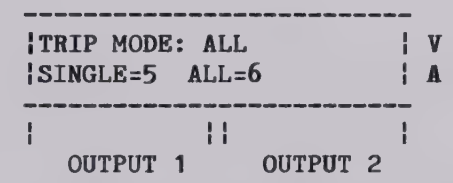


Output connections are as for isolated mode.

It is possible to set all parameters of the 2 outputs, except voltage, independently. The voltage on output 2 will automatically track any changes made on output 1. The two outputs are fully isolated and may be referred to each other in any way required.

3.4.4. TRIP (Display or change Trip Mode - OVP, thermal trip) - FUNCTION 6

This operation functions globally for both output modules. It is used to define what happens to unaffected outputs when another output trips out due to OVP or temperature.

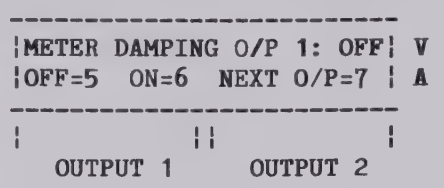


When SINGLE is selected only the affected output module will shut down. When ALL is selected both output modules are shut down if any trips are triggered.

When the required Trip Mode is set pressing the **ENTER** key will install the mode and exit the menu. Pressing the **ESCAPE** key will return to normal level with no changes.

3.4.5. DAMP (Display or change readback meter damping) - FUNCTION 7

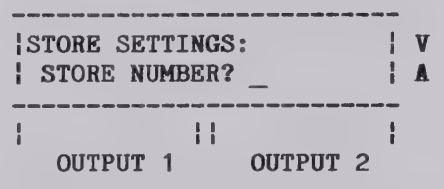
This operation functions only for the selected output module. To change the damping for another module it must first be selected in the normal way; alternatively key 7 may be used to select the next module directly.



Keys 5 and **6** are used to select the required damping and the **ENTER** key will install the setting and exit the menu. Pressing the **ESCAPE** key will return to normal level with no changes.

3.4.6. STORE (Store instrument settings to specified store) - FUNCTION OVP

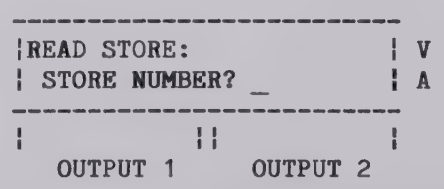
A complete instrument set-up may be saved to non-volatile memory by pressing the **FUNCTION** key followed by the OVP key and then entering the number of the required store. There are 25 stores numbered 1 to 25.



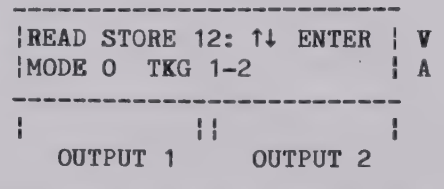
The required store number may be entered from the numeric pad followed by the **ENTER** key. As the entry is made the numbers will appear in the display at the cursor position and the cursor will move right. The **CE** key will move the cursor left one position and delete the digit at that position. Pressing the **ENTER** key will complete the operation and the display will return to normal level. The **ESCAPE** key may be used at any time to abort the entry and leave the stores unchanged.

3.4.7. READ (Show instrument settings from specified store) - FUNCTION RCL

This function allows the parameters in any store to be read without actually recalling them. This is useful to verify that the values are as expected.



Enter the number of the required store as for Store settings above and press the **ENTER** key. The display will change as shown below.

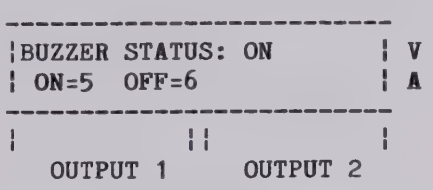


This shows the first values from the store. The **UP-ARROW** and **DOWN-ARROW** keys

may be used to cycle through all values. Pressing the **ENTER** key or the **ESCAPE** key will return to normal level.

3.4.8. ♪ (Display or change buzzer status) - FUNCTION 8

This function allows the buzzer to be turned ON or OFF. The buzzer normally sounds when errors occur but if this feature is not required it may be suppressed.



Keys 5 and 6 are used to select the required buzzer status and the **ENTER** key will install the setting and exit the menu. Pressing the **ESCAPE** key will return to normal level with no changes.

3.4.9. MSG (Display GPIB messages on LCD) - FUNCTION .

This option is provided for testing purposes when using the instrument on the GPIB. After execution of the function sequence the display will be cleared and the Remote led will be on. The keyboard is now locked in the same way as when the GPIB controller addresses the instrument, see GPIB section for more details of remote operation. The display will now show messages exactly as they are received, or sent, on the GPIB. To exit from this mode the **LOCAL** key must be pressed.

Whilst in message mode the instrument will respond normally to all bus operations but the response time will be considerably longer because the messages are held on the display long enough to be read. For this reason it is recommended that message mode is only used for testing.

3.4.10. CAL (Enter calibration mode) - FUNCTION CE

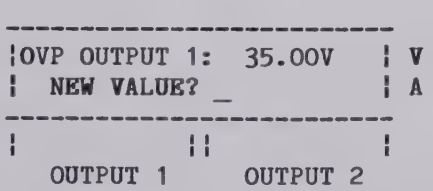
This is the production calibration mode; refer to the TSP3222 service manual for more details.

3.5. DIRECT OPERATIONS

These operations cause a switch to menu mode from a single key press rather than a function sequence.

3.5.1. Display or change OVP trip voltage for selected output - OVP

This operation functions only for the selected output module; to change the OVP for another module it must first be selected.



A new value may be entered from the numeric keypad and terminated by **ENTER**; the new value will be in Volts. Numeric entries will appear at the cursor position and the cursor will move right. The **CE** key will move the cursor left one position and delete the digit at that position. Pressing the **ENTER** key

will change the corresponding value to the newly entered value. The **ESCAPE** key may be used at any time to abort the entry and leave the value unchanged.

There are four possible causes of OVP trip, these are listed below together with the action taken in each case.

1. An external condition caused the output voltage to rise above the OVP trip value. A self-test is performed on the output. If all is well the output will be usable again, otherwise the output will be marked as failed.

2. The voltage has been set higher than the OVP trip value. The voltage will be set to 0.5 Volts below the OVP trip value and a self-test performed on the output. If all is well the output will be usable again, otherwise the output will be marked as failed.

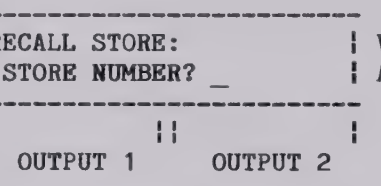
3. A hardware failure. A self-test is performed on the output. If all is well the output will be usable again, otherwise the output will be marked as failed.

4. There was an attempt to draw current from the sense terminals. A self-test is performed on the output. If all is well the output will be usable again, otherwise the output will be marked as failed.

In all cases the output status of the affected supply will be set to OFF and it will be necessary to set it back to ON before the supply can be used again.

3.5.2. Recall settings - RCL

A complete instrument set up may be retrieved from non-volatile storage by a 'recall' sequence. This is initiated by pressing the **RCL** key followed by the number of the required store. There are 25 stores numbered 1 to 25.



The required store number may be entered from the numeric pad followed by the **ENTER** key. As the entry is made the numbers will appear in the display at the cursor position and the cursor will move right. The **CE** key will move the cursor left one position and delete the digit at that position. Pressing the **ENTER** key will complete the operation and the display will return to normal level. The **ESCAPE** key may be used at any time to abort the entry and leave the settings unchanged.

3.6. CONNECTION TO THE LOAD.

Both outputs are fully floating and either can be connected to ground. Either output terminal can be raised to 300V above true ground; however, such voltages are hazardous and great care should be taken.

Note that there is a capacitor permanently across the output of the power supply to provide stability and good transient response. This capacitor will be charged to the set output voltage when the output switch is OFF. This means that if a low impedance load is connected to the output terminals and the output is switched to the ON position a pulse of current will flow into the load until the capacitor discharges, independent of the current limit setting.

3.6.1. Sense Terminals

To eliminate the errors that can be introduced by connection lead resistance, the remote sensing facility should be used (0.1 Ohm of lead resistance will drop 0.2V at 2A). The sense terminals are located on the rear panel next to the duplicate output terminals. Remove the two shorting bars and connect the sense terminals directly to the load. To ensure good coupling between the output and sense terminals, the sense wires should be twisted with their corresponding output leads. Alternatively coaxial cable can be used, with the inner used for sensing. When using remote sensing the voltage drop in each output lead must not exceed 0.4V.

3.6.2. Protection

The power supply cannot sink current provided by an external source. If an external source greater than OVP is connected to the output terminals with the output switch ON, OVP will trip.

The power supply is protected from reverse voltages by a diode; the reverse current must not exceed 3 Amps.

4. TSP32XX Series Power Supplies GPIB Commands and Status Reporting

4.1. INTRODUCTION

The following sections describe the GPIB commands, status model, error reporting and error numbers for the TS32XX series power supplies.

All instruments in the range comply with IEEE Std. 488.1-1987 and IEEE Std. 488.2-1987 and contain the following IEEE 488.1 subsets:

Source Handshake	SH1
Acceptor Handshake	AH1
Talker	T6
Listener	L4
Service Request	SR1
Remote Local	RL1
Parallel Poll	PP1
Device Clear	DC1
Device Trigger	DT0 *
Controller	C0
Electrical Interface	E2

* Although no Device Trigger capability is included the GET message will not cause a command error unless its position in the input stream dictates that it should; e.g. buried inside a <PROGRAM MESSAGE UNIT>.

GPIB input to the instrument is buffered in a 256 byte input queue which is filled, under interrupt, in a manner transparent to all other instrument operations. This queue contains raw (un-parsed) data which is taken, by the parser, as required. Commands (and queries) are executed in order and the parser will not start a new command until any previous command or query is complete. There is no output queue which means that the response formatter will wait, indefinitely if necessary, until the instrument is addressed to talk and the complete response message has been sent, before the parser is allowed to start the next command in the input queue. Bus commands and responses take priority over display updates (except when in message mode) so during times of intense bus activity between controller and instrument the display is blanked.

Commands are sent as <PROGRAM MESSAGES> by the controller, each message consists of zero or more <PROGRAM MESSAGE UNIT> elements separated by <PROGRAM MESSAGE UNIT SEPARATOR> elements.

<PROGRAM MESSAGES> are separated by <PROGRAM MESSAGE TERMINATOR> elements which may be any of the following:

NL	The new line character (0AH)
NL^END	The new line character with the END message
^END	The END message with the last character of the message

A <PROGRAM MESSAGE UNIT SEPARATOR> is the semi-colon character ';' (3BH).

A <PROGRAM MESSAGE UNIT> is any of the commands in sections 4.7.1. and 4.7.2.

Responses from the instrument to the controller are sent as <RESPONSE MESSAGES>. A <RESPONSE MESSAGE> consists of one <RESPONSE MESSAGE UNIT> followed by a <RESPONSE MESSAGE TERMINATOR>.

A <RESPONSE MESSAGE TERMINATOR> is the new line character with the END message NL^END.

Each query produces a specific <RESPONSE MESSAGE> which is listed along with the command in sections 4.7.1. and 4.7.2.

<WHITE SPACE> is ignored except in binary blocks and command identifiers. e.g. '*C LS' is not equivalent to '*CLS'. <WHITE SPACE> is defined as character codes 00H to 20H inclusive with the exception of the NL character (0AH).

The high bit of all characters is ignored except in binary blocks.

The commands are case insensitive.

The command sections use the following nomenclature:

<pmt>	<PROGRAM MESSAGE TERMINATOR>
<rmt>	<RESPONSE MESSAGE TERMINATOR>
<nrf>	A number in any format. e.g. 12, 12.00, 1.2 e1 and 120 e-1 are all accepted as the number 12. Any number, when received, is converted to the required precision consistent with the use then rounded up to obtain the value of the command.
<nr1>	A number with no fractional part, i.e. an integer.
<nr2>	A number in fixed point format, e.g. 11.52, 0.78 etc.

The IEEE 488.2 UNTERMINATED error (addressed to talk with nothing to say) is handled as follows. If the instrument is addressed to talk **and** the response formatter is inactive **and** the input queue is empty **then** the UNTERMINATED error is generated. This will cause the Query Error bit to be set in the Standard Event Status Register, a value of 3 to be placed in the Query Error Register and the parser to be reset. See section 4.6. for a full description of the instrument status reporting capabilities.

The IEEE 488.2 INTERRUPTED error is handled as follows. If the response formatter is waiting to send a response message **and** a <PROGRAM MESSAGE TERMINATOR> has been read by the parser **or** the input queue contains more than one END message) **then** the instrument has been INTERRUPTED and an error is generated. This will cause the Query Error bit to be set in the Standard Event Status Register, a value of 1 to be placed in the Query Error Register and the response formatter to be reset thus clearing the output queue. The parser will then start parsing the next <PROGRAM MESSAGE UNIT> from the input queue. See section 4.6. for a full description of the instrument status reporting capabilities. Note that it is not possible to detect <PROGRAM MESSAGE TERMINATOR> elements which are just the NL character (0AH) in the un-parsed input queue and this may cause the instrument to erroneously miss the INTERRUPTED condition. This is because the meaning of a NL character in the input queue is context dependent: e.g. it may be a legitimate <PROGRAM MESSAGE TERMINATOR> or simply a byte in a binary data block. This omission from the implementation of the standard does not cause any problems in use and does not exist at all if all <PROGRAM MESSAGE TERMINATOR> elements use the END message.

The IEEE 488.2 DEADLOCK error is handled as follows. If the response formatter is waiting to send a response message **and** the input queue becomes full **then** the instrument enters the DEADLOCK state and an error is generated. This will cause the Query Error bit to be set in the Standard Event Status Register, a value of 2 to be placed in the Query Error Register and the response formatter to be reset thus clearing the output queue. The parser will then start parsing the next <PROGRAM MESSAGE UNIT> from the input queue. See section 4.6. for a full description of the instrument status reporting capabilities.

4.2. BUS ADDRESS

The TS32XX series power supplies are capable of operation at any address between 0 and 30 inclusive. The address is set from the keyboard as described

in section 3.4.2. It is not possible to change the address using bus commands. A change of address will become active immediately it is entered from the keyboard and the device will no longer respond to the previous address. It is not possible to set the address outside the range 0 to 30 inclusive.

All device operations are performed through a single primary address, no secondary addressing is used. The default address, i.e. after a non-volatile ram failure, is 11. When the address is changed the new setting is stored in non-volatile ram and will remain unchanged even while power is off.

4.3. POWER ON SETTINGS

Most instrument settings are stored in non-volatile ram and will remain unchanged while power is off. The following instrument status values are set at power on:

Status Byte Register	= 0	
Service Request Enable Register	= 0	
Standard Event Status Register	= 128	(pon bit is set)
Standard Event Status Enable Register	= 0	
Limit Event Status Register	= 0	(Then set to show new limit status)
Limit Event Status Enable Register	= 0	
Execution Error Register	= 0	
Query Error Register	= 0	
Parallel Poll Enable Register	= 0	

The standby state will be set and the instrument will be in local with the keyboard active. A complete self-test will be performed just after power up and this will determine the values in the Failed Output Register and the state of the FLT bit in the Status Byte Register.

Due to this non-volatile storage the power on settings are essentially modified by any command, local or remote, which changes any value not listed above. If a defined state is required at start up by the controller the *RST command should be issued which will load the settings as listed in the description of that command.

If for any reason an error is detected at power up in the non-volatile ram a warning will be issued and all settings will be returned to their default states as for a *RST command see section 4.7.1.

4.4. REMOTE/LOCAL OPERATION

At power-on the instrument will be in the local state with the REMOTE led off. In this state all keyboard operations are possible. When the instrument is addressed (to talk or listen) the remote state will be entered and the REMOTE led will be turned on. In this state the keyboard is locked out and remote commands only will be processed. The instrument may be returned to the local state by pressing the **LOCAL** key; however, the effect of this action will remain only until the instrument is addressed again or receives another character from the GPIB, when the remote state will once again be entered. The Controller may disable the LOCAL key by sending a Local Lock Out command (LLO); the instrument keyboard will then remain inoperative until the Controller sends a Go To Local command (GTL) or sets the REN interface line false.

4.5. PARALLEL POLL

The TSP32XX series of power supplies offer complete parallel poll capabilities.

The Parallel Poll Enable Register is set to specify which bits in the Status Byte Register are to be used to form the **ist** local message The Parallel Poll Enable Register is set by the *PRE <nrf> command and read by the *PRE? command. The value in the Parallel Poll Enable Register is ANDed with the Status Byte Register; if the result is zero then the value of **ist** is 0 otherwise the value of **ist** is 1.

The instrument must also be configured so that the value of **ist** can be returned to the controller during a parallel poll operation. The instrument is configured by the controller sending a Parallel Poll Enable command (PPE) followed by a Parallel Poll Configure command (PPC). The bits in the PPC command are shown below:

```
bit 7 = X = don't care
bit 6 = 1   \
bit 5 = 1    |- Parallel poll configure
bit 4 = 0   /
bit 3 = Sense - sense of the response bit; 0 = low, 1 = high
bit 2 = ?   \
bit 1 = ?    |- bit position of the response
bit 0 = ?   /
```

Example. To return the RQS bit (bit 6 of the Status Byte Register) as a 1 when true and a 0 when false in bit position 1 in response to a parallel poll operation send the following commands

```
*pre 64<pmt>
then PPE followed by 69h
```

The parallel poll response from the power supply will then be 00h if RQS is 0 and 01h if RQS is 1.

During parallel poll response the DIO interface lines are resistively terminated (passive termination). This allows multiple devices to share the same response bit position in either wired-AND or wired-OR configuration, see IEEE 488.1 for more information.

4.6. STATUS REPORTING CAPABILITIES

This section describes the complete status model of the instrument.

4.6.1. Standard Event Status and Standard Event Status Enable Registers

These two registers are implemented as required by the IEEE std. 488.2.

Any bits set in the Standard Event Status Register which correspond to bits set in the Standard Event Status Enable Register will cause the ESB bit to be set in the Status Byte Register.

The Standard Event Status Register is read and cleared by the *ESR? command. The Standard Event Status Enable register is set by the *ESE <nrf> command and read by the *ESE? command.

Bit 7 - Power On. Set when power is first applied to the instrument.

Bit 6 - Not used.

Bit 5 - Command Error. Set when a syntax type error is detected in a command from the bus. The parser is reset and parsing continues at the next byte in the input stream.

Bit 4 - Execution Error. Set when an error is encountered while attempting to execute a completely parsed command. The appropriate error number will be reported in the Execution Error Register as listed below.

100	Maximum set voltage value exceeded
101	Maximum set Amps value exceeded
102	Minimum set voltage exceeded
103	Minimum set Amps value exceeded
104	Temperature tripped
106	Tracking mode requested is illegal
107	Minimum set OVP value exceeded
108	Maximum set OVP value exceeded
109	Ovp tripped
110	Can't set or read Volts on a slave output
111	Can't set or read current on slave output (except if tracking)
112	Mode requested is illegal
113	Can't turn a slave output on or off
115	Illegal store number
116	Recall empty store requested
117	Stored data is corrupt
118	Can't set or read OVP on a slave
119	Value out of range
200	Operation attempted on faulty output

Bit 3 - Operation Time-out Error. Set when an attempt is made to set an output to a specific voltage value and the output Volts do not settle within 5 seconds. This can happen if, for example, a large value of capacitance exists across the output and the current limit is set to a very low value.

Bit 2 - Query Error. Set when a query error occurs. The appropriate error number will be reported in the Query Error Register as listed below.

1	Interrupted error
2	Deadlock error
3	Unterminated error

Bit 1 - Operation Complete. Set in response to the *OPC command.

4.6.2. Limit Event Status Register and Limit Event Status Enable Register

These two registers are implemented as an addition to the IEEE std. 488.2. Their purpose is to allow the controller to be informed of entry to and/or exit from current limit by any output.

Any bits set in the Limit Event Status Register which correspond to bits set in the Limit Event Status Enable Register will cause the LIM bit to be set in the Status Byte Register.

The Limit Event Status Register is read and cleared by the LSR? command. The Limit Event Status Enable register is set by the LSE <nrf> command and read by the LSE? command.

bits 7-4 - Output n Voltage Limit. These bits, one for each output, will be set while the respective output is in voltage limit (i.e. not in current limit).

bits 3-0 - Output n Current Limit. These bits, one for each output, will be set while the respective output is in current limit.

4.6.3. Status Byte Register and Service Request Enable Register

These two registers are implemented as required by the IEEE std. 488.2.

Any bits set in the Status Byte Register which correspond to bits set in the Service Request Enable Register will cause the RQS/MSS bit to be set in the Status Byte Register, thus generating a Service Request on the bus.

The Status Byte Register is read either by the *STB? command, which will return MSS in bit 6, or by a Serial Poll which will return RQS in bit 6. The Service Request Enable register is set by the *SRE <nrf> command and read by the *SRE? command.

Bit 7 - FLT. This is the fault bit which will be set when an output is detected to have failed. This may happen either as a result of a self-test, in response to a *TST? command, or during an automatic test performed after OVP TRIP or TEMPERATURE TRIP has occurred. When this bit is set the internal Failed-output register will contain one or more of the following error numbers:

```
11      Current limit hardware failed - output 1
12      ditto                         - output 2
12      ditto                         - output 3
14      ditto                         - output 4
21      Ovp trip hardware failed      - output 1
22      ditto                         - output 2
23      ditto                         - output 4
24      ditto                         - output 4
31      Ovp trip and current limit hardware failed - output 1
32      ditto                                      - output 2
33      ditto                                      - output 3
34      ditto                                      - output 4
41      Set Volts hardware failure    - output 1
42      ditto                         - output 2
43      ditto                         - output 3
44      ditto                         - output 4
51      Volts or current readback A to D failed - output 1
52      ditto                                   - output 2
53      ditto                                   - output 3
54      ditto                                   - output 4
61      Set Volts and OVP failed hardware failed - output 1
62      ditto                                    - output 2
63      ditto                                    - output 3
64      ditto                                    - output 4
71      Fuse blown or transformer faulty or voltage hardware fail - output 1
72      ditto                                                     - output 2
73      ditto                                                     - output 3
74      ditto                                                     - output 4
```

The Failed-output register may be read by the TST? command.

Bit 6 - RQS/MSS. This bit, as defined by IEEE Std. 488.2, contains both the Requesting Service message and the Master Status Summary message. RQS is returned in response to a Serial Poll and MSS is returned in response to the *STB? command.

Bit 5 - ESB. The Event Status Bit. This bit is set if any bits set in the Standard Event Status Register correspond to bits set in the Standard Event Status Enable Register.

Bit 4 - MAV. The Message Available Bit. This will be set when the instrument has a response message formatted and ready to send to the controller. The bit will be cleared after the Response Message Terminator has been sent.

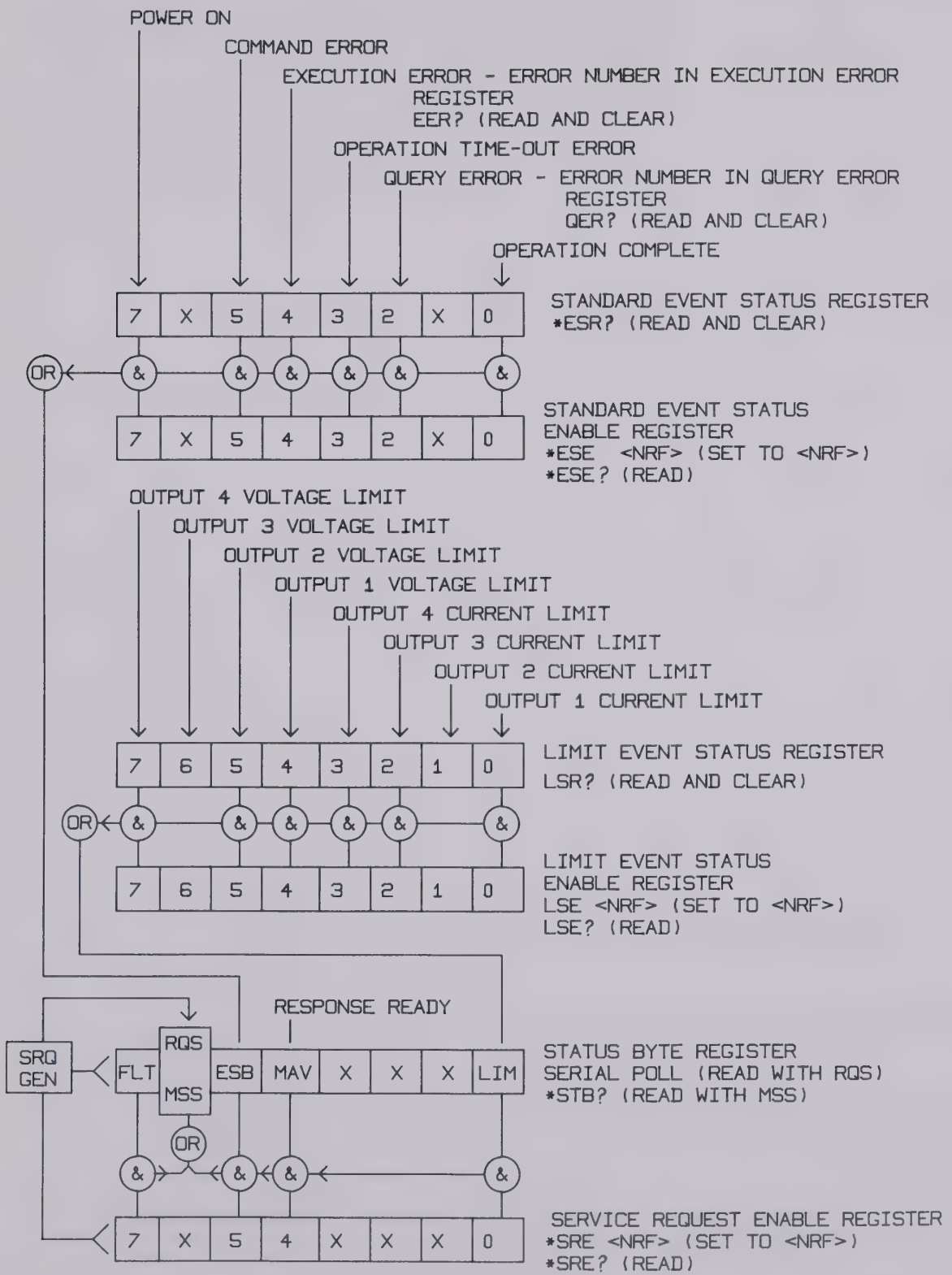
Bit 3 - Not used.

Bit 2 - Not used.

Bit 1 - Not used.

Bit 0 - LIM. The Limit status bit. This bit is set if any bits set in the Limit Event Status Register correspond to bits set in the Limit Event Status Enable Register.

4.6.4 Status Model



4.7. REMOTE COMMANDS

The following sections list all commands and queries implemented in the TS32XX series power supplies.

Note that there are no dependent parameters, coupled parameters, overlapping commands, expression program data elements or compound command program headers and that each command is completely executed before the next command is started.

4.7.1. Common Commands

The commands in this section are those specified by IEEE Std. 488.2 as Common commands.

***CLS**
Sequential command.
Operation complete message generated immediately after execution.

Clear status. Clears the Standard Event Status Register, Limit Event Status Register, Query Error Register and Execution Error Register. This indirectly clears the Status Byte Register.

***ESE <nrf>**
Sequential command.
Operation complete message generated immediately after execution.

Set the Standard Event Status Enable Register to the value of <nrf>. If the value of <nrf>, after rounding, is less than 0 or greater than 255 an execution error is generated and error number 119 (Byte value out of range) is placed in the Execution Error Register.

***ESE?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value in the Standard Event Status Enable Register in <nr1> numeric format. The syntax of the response is

<nr1><rmt>

Example. If the Standard Event Status Enable Register contains 01000001b the response to *ESE? will be 65<rmt>.

***ESR?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value in the Standard Event Status Register in <nr1> numeric format. The register is then cleared. The syntax of the response is

<nr1><rmt>

Example. If the Standard Event Status Register contains 01000001b the response to *ESR? will be 65<rmt>.

***IDN?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the instrument identification. The exact response is determined by the instrument configuration and is of the form

THANDAR,TSP<model>,0,<version><rmt>

where <model> defines the type of instrument e.g. 3224, and <version> is the revision level of the software installed e.g. 1.00.

***IST?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns ist local message as defined by IEEE Std. 488.2. The syntax of the response is

0<rmt>

if the local message false or

1<rmt>

if the local message is true.

***LRN?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the complete set up of the instrument as an Indefinite Length Binary Block. The block is prefixed with the LRN command and may thus be returned to the instrument to re-install the set up. The syntax of the response is

LRN #0<Indefinite Length Binary Block data><rmt>

The size of the data block is instrument type dependent; for the TSP3222 it is 38 bytes.

The settings in the instrument are not affected by execution of the *LRN? command.

***OPC**
Sequential command.
Operation complete message generated immediately after execution.

Sets the Operation Complete bit (bit 0) in the Standard Event Status Register. This will happen immediately the command is executed because of the sequential nature of all operations.

***OPC?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Query operation complete status. The syntax of the response is

1<rmt>

The response will be available immediately the command is executed because of the sequential nature of all operations.

***PRE <nrf>**
Sequential command.
Operation complete message generated immediately after execution.

Set the Parallel Poll Enable Register to the value <nrf>. If the value of <nrf>, after rounding, is less than 0 or greater than 255 an execution error is generated and error number 119 (Value out of range) is placed in the Execution Error Register.

***PRE?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value in the Parallel Poll Enable Register in <nr1> numeric format. The syntax of the response is

<nr1><rmt>

Example. If the Parallel Poll Enable Register contains 01000001b the response to *PRE? will be 65<rmt>.

***RST**
Sequential command.
Operation complete message generated immediately after execution.

Resets the instrument as follows. All outputs are set to minimum voltage, minimum current, maximum OVP, meter damping off and output OFF. The mode is set to 0 with no tracking. Shutdown mode is ALL and Master is OFF. No other action is taken.

***RCL <nrf>**
Sequential command.
Operation complete message is generated once the new output voltages have settled to within 20mV of the required value. If the voltages fail to settle within 5 seconds the Operation Time-out Error (bit 3 in the Standard Event Status Register) will be set and the operation complete message will then be generated.

Recall settings from store number <nrf>. The settings in the store pointed to by <nrf> are recalled and installed as the instrument settings. If the value of <nrf>, after rounding, is less than 1 or greater than 25 an execution error is generated and error number 115 (illegal store number) is placed in the Execution Error Register. If the requested store is empty execution error 116 (Recall empty store requested) is generated. If the contents of the selected store are corrupt execution error 117 (Stored data is corrupt) is generated. Any of the above error conditions will result in no change of the instrument settings.

The scope of the *RCL command is as follows:

All outputs set to stored values of Volts, current, OVP and meter response.
The output status of each output is set to the stored value.
Mode and tracking is set to stored value.
Shutdown mode and Standby condition are set to stored values.

***SRE <nrf>**
Sequential command.
Operation complete message generated immediately after execution.

Set the Service Request Enable Register to <nrf>. If the value of <nrf>, after rounding, is less than 0 or greater than 255 an execution error is generated and error number 119 (Value out of range) is placed in the Execution Error Register.

***SRE?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value of the Service Request Enable Register in <nr1> numeric format. The syntax of the response is

<nr1><rmt>

Example. If the Service Request Enable Register contains 01000001b the response to *SRE? will be 65<rmt>.

***STB?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value of the Status Byte Register in <nr1> numeric format. The syntax of the response is

<nr1><rmt>

Example. If the Status Byte Register contains 01000001b the response to *STB? will be 65<rmt>.

***SAV <nrf>**
Sequential command.
Operation complete message generated immediately after execution.

Save settings to store no <nrf> The instrument settings are saved in the store pointed to by <nrf>. If the value of <nrf>, after rounding, is less than 1 or greater than 25 an execution error is generated and error number 115 (illegal store number) is placed in the Execution Error Register.

The scope of the *SAV command is as follows;

The values of Volts, current, OVP and meter response are saved.
The output status of each output is saved.
Mode and tracking is saved.
Shutdown mode and Standby condition are saved.

***TST?**
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Execute self-test and return result. All outputs are tested (with the output off) if all pass the test the response is

0<rmt>

any failure is indicated by a non-zero fail code response in <nr1> format. Only the fail code of the lowest output to fail is returned, the TST? command may be used to obtain a full report on the self-test.

The test performed on each output is dependent on the type of output. See section 5. for a description of the types of self-test.

***WAI**
Sequential command.
Operation complete message generated immediately after execution.

Wait for operation complete true. As all commands are completely executed

before the next is started this command takes no additional action.

4.8. OTHER INSTRUMENT COMMANDS

The commands in this section are additional to those specified by IEEE Std. 488.2 as Common commands.

Many of these commands are specific to a particular output, the relevant output being specified as a number within the command header. For example V1 20 sets the voltage of output 1 to 20V, V2 20 performs the same operation but on output 2. These multi-output commands are listed as a single command with <n> replacing the required output number. The number of the particular output should be substituted when sending the command to the instrument. If a command is sent which specifies an output which is not available in the instrument a command error will be generated.

When outputs are specified as Series, Parallel or Tracking most operations are allowed only on the master (lowest number output). The only legal slave operation is the setting of current on a tracking slave. Illegal operations of this type will result in an execution error and one of the following error numbers in the Execution Error Register.

110	Can't set or read Volts on a slave output
111	Can't set or read current on slave output (except tracking)
113	Can't turn a slave output on or off
118	Can't set or read OVP on a slave

If a trip occurs at any time (OVP or temperature) an execution error will be generated and the error number in the Execution Error Register will be one of the following

104	Temperature tripped
109	Ovp tripped

The OVP trip will be cleared automatically and the relevant output tested. If the test is passed the output will then be usable again. However, if the test fails the output will be marked as faulty and any further operations attempted on it will generate an execution error and the number in the Execution Error Register will be

200	Operation attempted on faulty output

This error will also be generated if an operation is attempted on an output which is temperature tripped.

V<n> <nrf>
Sequential command.
Operation complete message is generated once the new output voltages have settled to within 20mV of the required value. If the voltages fail to settle within 5 seconds the Operation Time-out Error (bit 3 in the Standard Event Status Register) will be set and the operation complete message will then be generated.

Set voltage on output <n> to <nrf>. The value of <nrf> must be in Volts; no multipliers are allowed. If the value of <nrf>, after rounding, is outside the range of the specified output an execution error will be generated and the corresponding error number will be placed in the Execution Error Register, 100 (Maximum set voltage value exceeded) if the value is too large and 102 (Minimum set voltage exceeded) if the value is too small.

I<n> <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Set current limit on output <n> to <nrf>. The value of <nrf> must be in Amps; no multipliers are allowed. If the value of <nrf>, after rounding, is outside the range of the specified output an execution error will be generated and the corresponding error number will be placed in the Execution Error Register, 101 (Maximum set Amps value exceeded) if the value is too large or 103 (Minimum set Amps value exceeded) if the value is too small.

OVP<n> <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Set OVP on output <n> to <nrf>. The value of <nrf> must be in Volts; no multipliers are allowed. If the value of <nrf>, after rounding, is outside the range of the specified output an execution error will be generated and the corresponding error number will be placed in the Execution Error Register, 108 (Maximum set OVP value exceeded) if the value is too large or 107 (Minimum set OVP value exceeded) if the value is too small.

V<n>?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the set voltage on output <n> in Volts in <nr2> numeric format. The syntax of the response is

V<n> <nr2><rmt>

Example. If the set voltage on output 2 is 12.55 Volts the response to the command V2? will be V2 12.55<rmt>.

I<n>?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the current limit on output <n> in Amps in <nr2> numeric format. The syntax of the response is

I<n> <nr2><rmt>

Example. If the current limit on output 2 is 1.234 Amps the response to the command I2? will be I2 1.234<rmt>.

OVP<n>?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the OVP value on output <n> in Volts in <nr2> numeric format. The syntax of the response is

OVP<n> <nr2><rmt>

Example. If the OVP value on output 2 is 33.00 Volts the response to the command OVP2? will be OVP2 33.00<rmt>.

V<n>R?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Reads and returns the output voltage on output <n> in Volts in <nr2> numeric format. The syntax of the response is

<nr2>V<rmt>

Example. If the output voltage on output 2 is 12.55 Volts the response to the command V2R? will be 12.55V<rmt>.

I<n>R?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Reads and returns the output current on output <n> in Amps in <nr2> numeric format. The syntax of the response is

<nr2>A<rmt>

Example. If the output current on output 2 is 1.234 Amps the response to the command I2R? will be 1.234A<rmt>.

OP<n> <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Sets the output status of output <n> ON or OFF. If the value of <nrf>, after rounding, is 0 the output status will be set to OFF if 1 the output status will be ON. If the value of <nrf> is not 0 or 1 execution error 119 (Value out of range) will be generated.

DAMPING<n> <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Sets the meter damping of output <n> to OFF or ON. If the value of <nrf>, after rounding, is 0 the meter damping will be set to OFF, if 1 the meter damping will be set to ON. If the value of <nrf> is not 0 or 1 execution error 119 (Value out of range) will be generated.

MODE <nrfx>,<nrfy>,<nrfz>
Sequential command.
Operation complete message generated immediately after execution.

Sets the configuration mode of the instrument to MODE number <nrfx> and TRACKING to <nrfy> and <nrfz>. This command is not available in an instrument with a single output. For multi-output instruments the values are defined as follows.

The Mode number, <nrfx>, after rounding should be a value between 0 and 12 from the list below.

Mode	Number of Outputs	Description
0	2,3,4	All outputs isolated
1	2,3,4	Outputs 1 and 2 in series, outputs 3 and 4 isolated
2	3,4	Outputs 1 and 2 in parallel, outputs 3 and 4 isolated
3	4	Outputs 1 and 2 isolated, outputs 3 and 4 in series
4	4	Outputs 1 and 2 isolated, outputs 3 and 4 in parallel
5	3,4	Outputs 1 and 4 isolated, outputs 2 and 3 in series
6	4	Outputs 1 and 2 in series, outputs 3 and 4 in series
7	4	Outputs 1 and 2 in parallel, outputs 3 and 4 in parallel
8	4	Outputs 1 and 2 in series, outputs 3 and 4 in parallel
9	4	Outputs 1 and 2 in parallel, outputs 3 and 4 in series
10	3,4	Outputs 1 and 2 and 3 in series, output 4 isolated
11	4	Output 1 isolated, outputs 2 and 3 and 4 in series
12	4	Outputs 1 and 2 and 3 and 4 in series

If <nrfx> is not in this range or the requested mode is not available (e.g. modes 3 to 12 are not available on a instrument with 2 outputs only) execution error 112 (Mode requested is illegal) will be generated.

The values <nrfy> and <nrfz> are used to specify two possible tracking modes. Both may be specified only for a 4 output instrument. Each value is defined as follows.

The value, after rounding, is treated as a binary value the meaning of each bit (when set to 1) being shown in the table below.

bit 0	Output 1 tracking
bit 1	Output 2 tracking
bit 2	Output 3 tracking
bit 3	Output 4 tracking
bits 4 to 7	Not used, set to 0

At least 2 bits must be set to 1 to set two outputs tracking. If either of the tracking values is illegal execution error 106 (Tracking mode requested is illegal) will be generated.

Example. To set a 4 output instrument to all outputs isolated (Mode 0) with outputs 1 and 2 tracking and outputs 3 and 4 tracking use the command MODE 0,3,12

Example. To set a 4 output instrument to all outputs isolated with outputs 1 and 2 and 3 tracking use the command MODE 0,7,0.

MODE?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the Configuration Mode and Tracking of the instrument. The syntax of the response is

MODE <nr1x>,<nr1y>,<nr1z><rmt>

where <nr1x>, <nr1y> and <nr1z> are as specified in the MODE command.

TRIPMODE <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Sets the Trip (Shutdown) Mode of the instrument to ALL or SINGLE. If the value of <nrf>, after rounding, is 0 the trip mode will be set to ALL if 1 the trip mode will be SINGLE. If the value of <nrf> is not 0 or 1 execution error 119 (Value out of range) will be generated.

MASTER <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Sets the Master output switch of the instrument to ON or OFF. If the value of <nrf>, after rounding, is 0 the master switch will be set to OFF if 1 the master switch will be ON. If the value of <nrf> is not 0 or 1 execution error 119 (Value out of range) will be generated.

LSR?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value in the Limit Event Status Register in <nr1> numeric format. The register is then cleared. The syntax of the response is

<nr1><rmt>

Example. If the Limit Event Status Register contains 01000001b the response to LSR? will be 65<rmt>.

LSE <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Set the Limit Event Status Enable Register to the value of <nrf>. If the value of <nrf>, after rounding, is less than 0 or greater than 255 an execution error is generated and error number 119 (Value out of range) is placed in the Execution Error Register.

LSE?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value in the Limit Event Status Enable Register in <nr1> numeric format. The syntax of the response is

<nr1><rmt>

Example. If the Limit Event Status Enable Register contains 01000001b the response to LSE? will be 65<rmt>.

EER?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value in the Execution Error Register in <nr1> numeric format. The register is then cleared. The syntax of the response is

<nr1><rmt>

QER?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the value in the Query Error Register in <nr1> numeric format. The register is then cleared. The syntax of the response is

<nr1><rmt>

BUZZER <nrf>
Sequential command.
Operation complete message generated immediately after execution.

Sets the buzzer status to ON or OFF. If the value of <nrf>, after rounding, is 0 the buzzer status will be set to OFF if 1 the buzzer status will be set to ON. If the value of <nrf> is not 0 or 1 execution error 119 (Value out of range) will be generated.

BUZZ
Sequential command.
Operation complete message generated immediately after execution.

Sounds the buzzer and sets the buzzer status to ON.

TST?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the contents of the Failed-output register which contains the results of the last self-test operation performed either automatically as a result of power up or OVP/Temperature trips or in response to a *TST? command. The syntax of the response is

<nr1a>,<nr1b>,<nr1c>,<nr1d><rmt>

where <nr1a> is the last test result of output 1, <nr1b> is that for output 2 etc. A value of 0 indicates that the output is functioning correctly, any non-zero value indicates a fault. The fault codes are listed in section 4.6.3.

LRN #0<Indefinite Length Binary Block data><pmt>
Sequential command.
Operation complete message generated immediately after execution.

Install all instrument settings from a previous *LRN? query. The response from a *LRN? command is formatted such that the complete message may be returned to the instrument at any time to restore the settings in effect when the *LRN? command was issued.

The scope of the LRN command is as follows;

All outputs set to the values of Volts, current, OVP and meter response from the data block.
The output status of each output is set from the data block.
Mode and tracking is set from the data block.
Shutdown mode and Standby condition are set from the data block.

STO?
Sequential command.
Operation complete message generated immediately after <rmt> is sent.

Returns the contents of the stores in the instrument as an Indefinite Length Binary Block. The block is prefixed with the STO command and may thus be returned to the instrument to re-install the stored settings. The syntax of the response is

STO #0<Indefinite Length Binary Block data><rmt>

The size of the data block is instrument type dependent; for the TSP3222 it is 960 bytes

The settings in the instrument are not affected by execution of the STO? command.

STO #0<Indefinite Length Binary Block data><pmt>
Sequential command.
Operation complete message generated immediately after execution.

Install all stored data from a previous STO? query. The response from a STO? command is formatted such that the complete message may be returned to the instrument at any time to restore the data in effect when the STO? command was issued.

The instrument settings are not affected by the STO command but the contents of the stores are completely updated.

4.9. REMOTE COMMAND SUMMARY

Common commands

*CLS
*ESE <nrf>
*ESE?
*ESR?
*IDN?
*IST?
*LRN?
*OPC
*OPC?
*PRE <nrf>
*PRE?
*RST
*RCL <nrf>
*SRE <nrf>
*SRE?
*STB?
*SAV <nrf>
*TST?
*WAI

Other commands

V<n> <nrf>
I<n> <nrf>
OVP<n> <nrf>
V<n>?
I<n>?
OVP<n>?
V<n>R?
I<n>R?
OP<n> <nrf>
DAMPING<n> <nrf>
MODE <nrfx>,<nrfy>,<nrfz>
MODE?
TRIPMODE <nrf>
MASTER <nrf>
LSR?
LSE <nrf>
LSE?
EER?
QER?
BUZZER <nrf>
BUZZ
TST?
LRN #0<Indefinite Length Binary Block data><pmt>
STO?
STO #0<Indefinite Length Binary Block data><pmt>

5. Self Test Operation

The following is a description of the self test performed at power-up, as a result of a trip, or in response to the *TST? command.

The test is performed with the outputs switched off; it is self-contained and automatic. Outputs are tested in isolated mode, the mode being temporarily changed automatically if necessary. The operation is a confidence test and not a full specification parametric test.

5.1. 32V, 2A TYPE LINEAR OUTPUTS TEST

The test is as follows:

1. The outputs to be tested are switched off and the mode is set to isolated if required. Each output is then tested as follows.

2. Voltage is set to 32V, current is set to 2A, OVP is set to 35V.

3. The voltage is read back and a pass is logged if the value is 32V +/-100mV, otherwise a fail is logged.

4. OVP is then reduced until OVP trip is generated. If this happens in the range 31.60V to 32.40V a pass is logged, otherwise a fail is logged.

5. With OVP tripped the current is read back and a pass is logged if the value is 2.000A +/-5mA, otherwise a fail is logged.

6. The OVP trip is cleared and the voltage is read back. If the value is 32V +/- 100mV a pass is logged, otherwise a fail is logged.

7. If no failures are found the output and mode are set back to their original values otherwise a fault condition is flagged. Fault codes are as follows:

11	Current limit hardware failed	- output 1
12	ditto	- output 2
12	ditto	- output 3
14	ditto	- output 4
21	OVP trip hardware failed	- output 1
22	ditto	- output 2
23	ditto	- output 4
24	ditto	- output 4
31	OVP trip and current limit hardware failed	- output 1
32	ditto	- output 2
33	ditto	- output 3
34	ditto	- output 4
41	Set Volts hardware failure	- output 1
42	ditto	- output 2
43	ditto	- output 3
44	ditto	- output 4
51	Volts or current readback A to D failed	- output 1
52	ditto	- output 2
53	ditto	- output 3
54	ditto	- output 4
61	Set Volts and OVP failed hardware failed	- output 1
62	ditto	- output 2
63	ditto	- output 3
64	ditto	- output 4
71	Fuse blown or transformer faulty or voltage hardware fail	- output 1
72	ditto	- output 2

73	ditto	- output 3
74	ditto	- output 4

These codes appear on the display and are returned to the controller in response to the TST? and *TST? commands.

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